4.2 Hydrology and Groundwater

4.2.1 Impact Criteria and Methodology

Criteria of Significance

Appendix G (Environmental Checklist Form) of the CEQA *Guidelines* indicates that a project's effects on water resources could be significant if the project were to result in substantial degradation of surface or groundwater resources compared to prevailing conditions or were to increase the potential for substantial flooding, erosion, or siltation.

Substantial degradation refers to a change in water quality that results in exceedance of, or noncompliance with, a regulatory standard or a loss of one or more existing or potential beneficial uses of the water. An impact to water quality would be considered significant if it were to result in any of the following:

- Violation of water quality objectives stated in the Water Quality Control Plan for the San Francisco Bay Region (SFB-RWQCB 1995);
- Impairment of beneficial uses of waters of Bolinas Lagoon or its tributaries, as defined in the Water Quality Control Plan for the San Francisco Bay Region (SFB-RWQCB 1995);
- Water or sediment quality conditions that could be harmful to aquatic life or human health, even if an accepted standard were not formally violated;
- An increase of potential for substantial off-site flood hazard (substantial flood hazard is greater than one percent, or once in one hundred years), erosion, or sedimentation; or
- Uses or facilities that would substantially degrade surface or groundwater quality.

Judgment must be used in determining the potential for erosion or siltation, as well as in determining the significance of water quality and flood hazards where no standards or flood zones have been identified.

Criteria of Success

In addition to the above evaluation criteria, the potential for the alternatives to meet the project objectives is discussed in this section. The project objectives include restoring hydraulic functions to Bolinas Lagoon that existed circa the early 1950s, while minimizing the need for future human intervention to maintain those functions. The discussion of the physical effects of the alternatives on circulation patterns, volume and depth, and their implications for water chemistry, turbidity, and flow velocity forms a basis for the discussion of these functions in relation to other resource categories (biological, recreational, and visual).

Stated simply, the lagoon is a delicate transitional region between a freshwater and seawater environment that is capable of providing a rich diversity of habitats. The project area is recognized as valuable for the biological diversity it supports and for the benefits it provides to people. The interaction of the lagoon's setting (watershed processes and tidal processes) with its geometry is ultimately responsible for this diversity.

The accumulation of sediment in the lagoon is a natural process that already might have caused the lagoon to evolve into a lake or upland if it were not offset by two other processes: Global sea level rise and subsidence of the graben due to activity of the San Andreas Fault. Within the recent geologic past, the area that is now lagoon has probably experienced large fluctuations in its size and character, sometimes becoming upland and sometimes becoming an arm of Bolinas Bay. Left alone, the lagoon might survive the threat of closure of its inlet channel if the graben undergoes another episode of subsidence. It is almost certain that the fault processes that have maintained the lagoon will continue to occur. But the risk that the inlet channel will close and that more lagoon habitat will be lost before the next major subsidence event occurs is thought to be unacceptable, given the consequences of lagoon closure on the habitats and species that the lagoon supports.

Dredging the lagoon to remove sediment has one thing in common with the natural processes of graben subsidence and sea level rise that have served to preserve the lagoon: It increases the lagoon volume and the tidal prism. However, subsidence and sea level rise differ from dredging in that the first two increase depth over the entire area of the lagoon, while dredging increases depth in certain selected portions of the lagoon. Subsidence during an earthquake is a sudden event, while sea level rise is almost imperceptibly slow. But neither process substantially alters the shape of the bottom of the lagoon, so that established channels, islands, and deltas retain their forms and locations. Dredging, on the other hand, could dramatically alter the shape of the lagoon bottom, allowing for the creation of new channels and lowering or removing existing high points to achieve a desired effect. With this ability to reshape the lagoon comes a degree of uncertainty about the effects of the changes. However, altering the shape of the lagoon to meet human objectives is not something new in the lagoon's history. Seadrift Lagoon provides an observational reference for understanding how the larger lagoon responds to a major alteration of its geometry. Computer modeling can also help in predicting and comparing the hydrodynamic effects of specific alterations in the lagoon geometry.

4.2.2 Riparian Alternative

Significant Impacts

Impact 4.2.1: Subsidence Impacts from Earthquake Activity

The lagoon graben (the block of earth's crust underlying the lagoon that lies between two active traces of the San Andreas fault) could subside after the dredging project has been completed. As described for the No Action Alternative, a strong earthquake would liquefy the sand spit and probably level the lagoon bottom, as well as destroy structures underlain by sandy sediments. While not a direct impact of the project, these conditions would form the backdrop for additional hydraulic effects related to the project.

A one-foot drop in the lagoon floor after completion of the dredging project would probably increase the effective tidal prism by much more than 720,000 cy. Additional volume would also be added below the range of low tides. Because more of the lagoon would be below the tidal elevation for more of the tidal cycle, the movement of water into and out of the lagoon would be more efficient, increasing the effective tidal prism and creating higher tidal current velocities. The higher current velocities might increase both the width and the depth of the inlet channel and might further erode shallow portions of the lagoon.

This increase in the lagoon opening would allow larger waves to enter the lagoon, transferring wave energy farther into the lagoon. The lowering of Kent Island would also allow waves to move farther into the lagoon. The effect would be greatest during southerly or southwesterly storms that are associated with El Niño conditions. An increase in the amount of wave energy entering the mouth of the lagoon could lead to enhanced erosion of the cliffs along the west side of the inlet channel and other shoreline effects.

Assuming that one foot of subsidence occurred and that this increased the volume of the lagoon by 1.5 million cy, in addition to the increase of about 1.2 million cy from dredging (this does not include the volume of emergent land on Kent Island), the resulting increase in the tidal prism would be about 2.7 million cy. At the current estimated rate of 26,000 cy of net sediment deposition per year (which may be an overestimate, given the higher tidal velocities in the lagoon following such an increase), it would take more than 100 years for the tidal prism to decrease again to current levels.

Higher current velocities and more efficient tidal exchange would increase the rate at which freshwater is flushed out of the lagoon and would increase mixing of fresh and seawater in the lagoon. This would increase the average salinity of the waters inside the lagoon and would result in more homogeneous salinity throughout the lagoon.

Mitigation 4.2.1: No feasible mitigation has been identified for this impact.

Significant but Mitigable Impacts

Impact 4.2.2: Water Quality Impacts from Construction

During construction, dredging would increase suspended sediment in the vicinity of the dredging activity. Cutterhead suction dredges operate by cutting into the sediment with a rotating cutterhead, while the suction line behind the cutterhead pulls the disturbed sediment into it. There is always some “spill,” reportedly ranging from 5 percent to 40 percent of the disturbed material. This spilled material would be dispersed in the water surrounding the dredge and would be transported on currents. The percentage of spilled material generated would depend on the characteristics of the dredge, the angle of attack, and the way the dredge is operated. Once disturbed, sediment dispersion would depend on the sediment particle size and the current velocity. Sediment would be transported northward into the lagoon on flood tides and toward the inlet on ebb tides.

The bottom sediments consist of both fine-grained and coarse-grained sediments and organic matter, with coarse-grained sediments more abundant in the central lagoon. Coarse-grained sediments would be redeposited rapidly, while fine-grained sediments and organic matter would remain in suspension, increasing the turbidity of the water. Although some of the resuspended spilled sediment would be deposited in the interior of the lagoon, some would be transported out of the lagoon on ebb tides. Under a worst-case scenario, using the maximum dredging rate of 230 cy/hr and a moderate spillage rate of 20 percent, the spillage rate would be about 50 cy/hr. Assuming that half of the spilled sediment remains suspended in the water column for a six-hour tidal period, this would be an effective rate of sediment generation of 240 cy per tidal period. Assuming one ton per cubic yard, and further assuming a tidal exchange rate of about 4 million cy of water, this would result in an average increase in turbidity in the lagoon of about 50 milligrams per liter (mg/L), which is not significant. However, in practice the increase would be greatest near the dredge and would decrease farther from it. Depending on various factors, the turbidity could significantly increase near the dredge above background levels.

If enough decayed organic matter is suspended or dissolved in the water column, it may produce odors or change the chemical composition of the water, including decreasing pH and oxygen concentrations, increasing nitrogen and sulfide concentrations, and causing other chemical changes. Rapid changes in water chemistry might stimulate responses in the populations of organisms. Suspension of fine-grained sediments, either during dredging or when cut surfaces are exposed to high current velocities after dredging, could reduce water clarity in the lagoon. The magnitude and distribution of these water quality effects would depend on the nature of the sediments in the area being dredged, the method of dredging, and the velocity of currents that distribute the sediments after they are suspended. The effects of sediment disturbance would be greatest at times when the ambient water clarity is high and minor when the ambient water is already turbid, such as after a storm. Dredging is likely to take place during the summer and fall, when storms are less likely. Increased suspended sediment and changes in water quality are potentially significant, but mitigable, water quality impacts.

Some sediments in the lagoon may contain toxic compounds that when suspended could affect water quality. Former landfill materials along the margin of the lagoon may contain toxic substances. Runoff from farm areas to the North Basin, as well as rapid aquatic plant growth and decay in this area, may have resulted in organic matter accumulating and an oxygen-depleted, chemically reducing environment developing. Exposing these sediments by dredging and excavating could result in a significant but mitigable impact on water quality.

Mitigation 4.2.2: Sediment sampling and testing will be performed during the Project Engineering Design (PED) phase, to help identify potential conditions of concern to water quality prior to dredging. The use of small cutterhead dredges designed for minimizing sediment disturbance would reduce the impacts of turbidity. Sediment curtains or other barriers would be used, as needed, to isolate areas being dredged from ambient conditions. Water quality monitoring will enable dredging methods and practices to be adjusted to reduce adverse effects.

Impact 4.2.3: Long-Term Water Circulation Impacts

Changes in the shape of the bottom of the lagoon may substantially change circulation patterns within the lagoon, resulting in uncertain impacts. Many of the effects are likely to be beneficial because they will bring circulation to areas of the lagoon that have become isolated by sediment deposition. This is one of the intended effects of the alternative. The Riparian Alternative is intended to result in increased volume of tidal exchange, overall. However, the dynamic conditions to which the lagoon must adjust are complex, and the end result depends both on cyclical events and on the order in which noncyclical events occur. As a rule, the more alterations are made to the existing bottom topography, the less predictable would be the ultimate equilibrium bottom topography that results from the alterations, and therefore, the more likely that some additional adjustment of the bottom topography would be needed to correct an undesirable effect. Because the Riparian Alternative involves a large number of alterations, some of the results may not be desirable. An example of an undesirable result would be the creation of a large pool that does not fill or drain adequately and therefore experiences radical variations in water quality. Potentially adverse circulation impacts are expected to be mitigable.

Mitigation 4.2.3: Sediment transport modeling will be performed during PED. Potential adverse effects on lagoon circulation patterns will be identified by monitoring water quality and flow patterns, monitoring bathymetric changes, and observing the ways in which the lagoon geometry changes over time. If adverse effects are identified, the need for additional adjustments will be evaluated. Most of the adverse effects are expected to be identified during the construction period.

Less than Significant Impacts

Order of Project Implementation

The lagoon has evolved to its present state in response to a specific sequence of events (for example, large sediment inputs caused by logging, large storms, and subsidence) superimposed on a set of cyclical tidal events. These events tend to result in the network of branching tributary and distributary channels that circulate tidal waters into and out of the lagoon, somewhat in the way that lungs circulate oxygen and carbon dioxide to and from the blood. The sequential events are responsible for some of the larger features, such as islands, the Pine Gulch Creek delta, and the North Basin. The ultimate configuration of the lagoon is therefore highly influenced by the specific nature and order of the sequential events. In the same way, the ordering and rate of construction of project components may have an effect on the end result. For example, reestablishing the channel through Kent Island first may have a different outcome than doing it last. The impacts of the proposed order compared to some other order are uncertain. The proposed order is intended to maximize the early increase in tidal prism, both to achieve the greatest benefits and to enable the effects of the most substantial changes to be observed over the course of the construction period, when adjustments can be made most easily. One of the impacts of the proposed ordering of the construction schedule is that abrupt changes in water quality may occur early in the project, making it more difficult to discern the effects of small adjustments later on. The significance of the ordering is uncertain, and, other than altering the construction schedule in response to observations, there is no mitigation.

Water Quality in Bolinas Bay

Dredged sediments in a slurry form would be pumped to barges moored offshore in Bolinas Bay. The slurry would be contained in the barges and would not be dewatered before being transported to the disposal site. A rupture in the transfer pipeline could allow sediment to be pumped for a short time into Bolinas Bay until discovered and shut off. The volume of sediment released would not be large relative to normal sediment outflows following a rainfall/runoff event, for example. Therefore, water quality in Bolinas Bay is not expected to be significantly affected by the project.

Beneficial Impacts

The Riparian Alternative would increase the tidal prism, preventing the inlet channel from closing and maintaining tidal circulation in the lagoon, which would help to maintain the lagoon water quality. This is considered a beneficial impact of the alternative.

4.2.3 Estuarine Alternative

The Estuarine Alternative is nearly identical to the Riparian Alternative, and the water resources impacts are expected to be generally the same as those described for the Riparian Alternative, except those related to the dredging of the Pine Gulch Creek delta. Therefore, only the additional effects of this dredging are discussed below.

Significant but Mitigable Impacts

Impact 4.2.4: Water Quality Impacts from Excavation Materials

During delta dredging, spillage would contribute to turbidity. Deltaic sediments are rich in organic matter, and spilled sediment may enrich nutrient levels in the lagoon water, enhancing algae growth. Deltaic sediments are probably chemically reduced, so that when exposed to air, the sediments would liberate swampy odors and possibly some toxic forms of natural compounds, including ammonia and hydrogen sulfide.

Mitigation 4.2.4: The impacts of dredging on water quality would be carefully monitored to ensure that water quality is not significantly affected, and dredging would be performed slowly and during periods that are not critical for migrating fish. The rate of dredging may be reduced or the dredged area may be kept isolated from the lagoon to the extent necessary to maintain effects below a significant level.

Less than Significant Impacts

No other water resources impacts not previously identified for the Riparian Alternative are expected to result from the Estuarine Alternative.

Beneficial Impacts

The delta of Pine Gulch Creek is, like the channel of Pine Gulch Creek, a source of sediment to the lagoon. The distributary channels of Pine Gulch Creek can erode sediment stored on upland portions of the delta. Vegetation established on the delta helps to trap sediment and contributes to the growth of the delta. The geometry of the delta influences circulation patterns in the lagoon, for example, channeling sediment into the north lagoon. Removing portions of the delta would help to reverse these effects and would improve sediment transport from the lagoon.

4.2.4 No Action

Significant Impacts

Impact 4.2.5: Lagoon Closure

Under the No Action Alternative, the PGC Delta is projected to continue to build up and expand, and the tidal prism of the lagoon would continue to decrease. The effective tidal prism, as of 1998, was estimated from bathymetry and measured tide data inside the lagoon at 3,210,000 cy. The effective tidal prism is predicted to decrease to 1,640,000 cy by 2058, based on the current annual sedimentation rate. However, temporary or intermittent closure of the inlet channel is predicted as soon as 2058 (Corps 1999). This estimate is based on conservative assumptions and on the assumptions that there will be no major subsidence of the lagoon, and it takes into account only tidal flows, not freshwater inflows. When freshwater inflow is taken into account, the inlet channel would not begin to close until sometime after 2058.

Closure of the lagoon would allow the sand spit to extend across what is now the lagoon inlet channel. Wave action would build up the dune across the former inlet channel as it has built the dune elsewhere along the sand spit. This would create a dam or berm that would impound in the lagoon freshwater inflows from Pine Gulch Creek and other lagoon tributaries. Cut off from tidal exchange, the lagoon water chemistry would become increasingly dominated by freshwater inflows. A temporary freshwater/brackish water lake might form behind the sand spit, its depth and area depending on the rate of freshwater inflow. In the winter, when rainfall and runoff is higher, the lake level would rise. If left to natural processes, the elevation of the lake would be limited by the balance between inflow and losses from seepage through the sand spit and from evaporation. If inflows were great enough, the lake level would rise high enough to exceed the capacity of the berm formed by the beach sand dunes along the sand spit, and/or the sand spit might be eroded by winter storm waves. Eventually, the sand spit would be breached. The lake would then rapidly drain to the sea, and for a time the eroded breach in the sand spit would allow for tidal exchange into the lagoon/lake area. In practice, the lake level would probably rise too quickly, and the sand spit would need to be artificially breached to protect Highway 1 and other developed areas.

It could be possible to construct a permanent outlet structure for the freshwater so that it would not be necessary to breach the sand spit. This would result in the formation of a permanent channel and floodplain for Pine Gulch Creek and its tributaries. What is now the lagoon would remain low marshy ground, with areas below mean sea level. The other streams from the eastern slopes of the watershed would become tributaries to Pine Gulch Creek, as they extend their channels outward and join the main channel at points within what is now the lagoon. During the wet season, in high flows, the streams east of Highway 1 would continue to deposit a portion of their sediment loads upstream of Highway 1 to the extent that the culverts are undersized to accommodate storm flows.

Streams would remain within their channels as long as they were able to transport their sediment loads to the sea. However, the streams would adjust their gradients by depositing sediment in flat slow reaches or by eroding their channels in steep fast reaches until a channel network is created that transports the sediment load. In high flows, the area that is now the lagoon would be flooded periodically, and sediment would be deposited on the floodplain.

Inevitably, the graben underlying the lagoon would subside due to fault activity on the San Andreas Fault, as occurred in the 1906 earthquake. It is this periodic subsidence of Bolinas Lagoon by faulting that has maintained the lagoon when other tidal lagoons tend to fill with sediment and eventually evolve into woodlands. If the land surface subsides enough, tidal exchange to the low lying lands behind the sand spit could be reestablished, rejuvenating the tidal lagoon.

Intense ground shaking and extensive damage to property could occur as a result of a major earthquake on the San Andreas fault. Ground shaking would probably result in liquefaction of wet sandy sediments, which could cause foundations of structures constructed on the sand spit or other sandy areas with a shallow water table to sink.

The effects of closure of the lagoon inlet described above are considered significant because they would result in substantial changes in the lagoon geometry and function and in the water chemistry and beneficial uses of the lagoon. Because these changes would be due to natural conditions, they would not have regulatory significance. However, the changes in water quality and loss of a significant water resource (the lagoon) would be of a magnitude that would be considered significant if they were caused by human action. These impacts are not mitigable, except by increasing the tidal prism.

Significant but Mitigable Impacts

Impact 4.2.6: Flooding Impacts

The closure of the lagoon inlet could result in a significant increase in the risk of flooding of developed areas.

Mitigation 4.2.6: The hazard of flooding might be mitigable through engineering action to create a permanent outflow structure, but the feasibility of this has not been evaluated. Alternatively, the sand spit could be artificially breached, as needed, to prevent flooding. It is also possible that beach-building processes responsible for the expected closure of the inlet channel could be controlled by constructing groins, for example. Groins might prevent the accumulation of sand in the inlet channel and enable the channel to remain open despite a decreasing tidal prism. Any of these mitigation measures could reduce the risk of flooding to less than significant levels.

Less than Significant Impacts

Seismic and Subsidence Impacts

An earthquake of magnitude similar to the 1906 San Francisco earthquake is estimated to occur on average about once every 300 years on the portion of the San Andreas Fault that lies north of Monterey County. An earthquake of this magnitude, even if it were not centered near Bolinas Lagoon, might stimulate subsidence of the lagoon. The 1906 earthquake resulted in about one foot of subsidence in the lagoon. Assuming that one foot of subsidence occurred over the entire area of the current lagoon, it would result in a net increase in the effective tidal prism of about 720,000 cy (based on an effective tidal prism equal to 65 percent of the potential tidal prism and using the elevation-volume curve developed by the Corps [1999]). It would also increase the volume of the lagoon that lies deeper than the effective tidal prism by about 300,000 cy. The latter volume represents capacity for sediment storage that does not reduce the tidal prism. Assuming that the sedimentation rate remained at the current estimated rate of 26,000 cy per year, it would take approximately 46 years to fill this storage volume.

Under the subsidence scenario described above, the impacts of the No Action Alternative on water resources would be less than significant.